

8-1

00 III AR 655

GJO-99-132-TAR

MIRAPOU III AR 655 8-1 PERT WALL
PERT WALL FOR RADIONUCLIDES AND METALS -
PERFORMANCE SUMMARY 12/99

Permeable Reactive Treatment (PeRT) Wall for Radionuclides and Metals

Performance Summary Report for the PeRT Wall at Monticello, Utah

December 1999



U.S. Department
of Energy

GRAND JUNCTION OFFICE

Work Performed Under DOE Contract No. DE-AC13-96GJ87335 for the U.S. Department of Energy
Task Order Number MAC00-12

**Permeable Reactive Treatment (PeRT) Wall
for Radionuclides and Metals**

**Performance Summary Report
For the PeRT Wall at Monticello, Utah**

December 1999

Prepared for
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Office

Project Number PTW-121-0004-00-000
Document Number K00063AA

Work Performed Under DOE Contract Number DE-AC13-96GJ87335
Task Order Number MAC00-12

Cromwell, 1998. "Results of Preliminary Groundwater Flow Models for Baseline and Various Permeable Reactive Treatment (PeRT) Wall Configurations at Monticello, Utah." Memorandum to Mr. Paul Mushovic (U.S. Environmental Protection Agency, Region VIII) and Mr. David Bird (State of Utah Department of Environmental Quality) from Mr. Vernon Cromwell (DOE-Grand Junction Office) dated May 27.

"Flow Modeling Summary for Monticello PeRT Project," Letter to Vernon Cromwell, From Tim Bartlett, June 16, 1998.

MACTEC Environmental Restoration Services (MACTEC-ERS), "Monticello PeRT Project Field Characterization Summary," prepared by MACTEC-ERS for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, March.

———, 1999. *Final QC Plan, Revision 1, Slurry Wall Construction Monticello Permeable Reactive Treatment (PeRT) Project, Monticello, Utah*, May.

Memo to Permeable Reactive Treatment (PeRT) Wall File, From Clay Carpenter, "Potential Reduction in risks to Human health From Use of the PeRT Wall," March 31, 1998.

Morrison, S.J., 1998. *Research and Application of Permeable Reactive Barriers*, prepared for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, April.

Somerville, R.K., Z.M., 1999. "Grant of Easement," prepared by MACTEC Environmental Restoration Services for the U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, April.

U.S. Department of Energy, 1997. *Deployment Plan for the Permeable Reactive Treatment Wall for Radionuclides and Metals*, GJO-97-35-TAR, November.

———, 1998. *Permeable Reactive Treatment (PeRT) Wall Results of Laboratory Treatability Testing for the Monticello PeRT Wall*, GJO-98-52-TAR, prepared by MACTEC for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, May.

———, 1998. *Monticello Projects, Monticello Permeable Reactive Treatment Wall, Project Safety Plan for Monticello Millsite Permeable Reactive Treatment (PeRT) Wall Groundwater Treatment System*, Revision 0, MAC-PTW 2.1.3, prepared by MACTEC-ERS for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, August.

———, 1998. *Record of Decision for an Interim Remedial Action at the Monticello Mill Tailings Site, Operable Unit III—Surface Water and Ground Water, Monticello, Utah*, GJO-98-51-TAR, prepared by MACTEC Environmental Restoration Services for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, August.

———, 1998. *Permeable Reactive Treatment (PeRT) Wall, Characterization Report*, MAC-PTW 1.3-1, prepared by MACTEC-ERS for the U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, September.

Contents

	Page
Contents	iii
1.0 Introduction	1-1
1.1 Report Purpose	1-1
1.2 Project Background	1-1
2.0 As Built Construction Summary	2-1
3.0 Construction	3-1
3.1 Description of Activities	3-1
3.2 Construction Costs	3-1
3.3 Lessons Learned	3-1
4.0 Performance Monitoring	4-1
5.0 Overall Project Costs	5-1

Tables

Table 1.2-1	PeRT Wall Project Chronology	1-2
Table 3.2-1	PeRT Wall Construction Costs	3-1
Table 3.1-1	Construction Activities for the Monticello Millsite PeRT Wall Ground Water Treatment System	3-3
Table 4-1	PeRT Wall Sampling Data—September 1999	4-5
Table 5.1-1	PeRT Wall Project Costs	5-1

Figures

Figure 1.2-1.	PeRT Wall Location Map	1-3
Figure 3.1-1.	Mixing and Placing Soil/Bentonite Backfill for the North Slurry Wall	3-7
Figure 3.1-2.	Water/Bentonite Slurry in the South Slurry Wall	3-9
Figure 3.1-3.	Placing Soil/Bentonite Backfill in the North Slurry Wall Trench	3-11
Figure 3.1-4.	Crane (140 ton) With Vibratory Driver/Extractor Attached, Installing Sheet Piling	3-13
Figure 3.1-5.	Vibratory Driver/Extractor Installing Sheet Pilings	3-15
Figure 3.1-6.	Sheet Pile Box Looking North to South	3-17
Figure 3.1-7.	Sheet Pile Box With Structural beams and Cross bracing in Place	3-19
Figure 3.1-8.	Installation of Reactive Materials at Center 4 Feet of -8/+20 Mesh ZVI	3-21
Figure 3.1-9.	Completed Wall Covered with Geotextile Fabric	3-23
Figure 4-1.	Detail of the Performance Monitoring Well Network for the Gate Portion of the PeRT Wall	4-3
Figure 4-2.	Arsenic Sampling Data	4-7
Figure 4-3.	Iron Sampling Data	4-9
Figure 4-4.	Manganese Sampling Data	4-11
Figure 4-5.	Molybdenum Sampling Data	4-13
Figure 4-6.	Nitrate Sampling Data	4-15
Figure 4-7.	Selenium Sampling Data	4-17
Figure 4-8.	Uranium Sampling Data	4-19
Figure 4-9.	Vanadium Sampling Data	4-21

Appendices

Appendix A	PeRT Wall Bibliography.....	A-1
------------	-----------------------------	-----

1.0 Introduction

This document presents a summary of activities for the project: "Permeable Reactive Treatment Wall (PeRT) for Radionuclides and Metals." This project is being done under the auspices of the Accelerated Technology Deployment (ASTD) Program, sponsored by the U.S. Department of Energy's Office (DOE) of Science and Technology. The teaming partners on this project are the DOE-Grand Junction Office, Sandia National Laboratory, DOE Western Environmental Technology Office (MSE Technology Applications, Inc), and the University of Waterloo.

1.1 Report Purpose

The purpose of this report is to provide project tracking information, detailed information on the construction phase of the project, preliminary performance modeling results, and accurate project cost data. It is intended to be useful for personnel from other sites who are considering the use of a PeRT wall.

1.2 Project Background

A PeRT wall is a passive remediation system that chemically reduces concentrations of contaminants as they pass through reactive material. In the late spring of 1999, a PeRT wall was constructed downgradient of the Monticello Mill Tailings Site (MMTS) to clean up contaminated groundwater.

The MMTS is located near Monticello, Utah (see Figure 1.2-1), and is a former uranium and vanadium processing site which operated from the mid-1940's until 1960. The MMTS was placed on the National Priority List (NPL) in 1989 because of potentially elevated risks associated with contaminated materials related to past milling activities. This site is currently being remediated in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The DOE, U.S. Environmental Protection Agency (EPA), and the State of Utah have entered into a Federal Facilities Agreement (FFA) that specifies DOE as the lead agency and gives oversight authority to EPA and the State. After the ASTD program was established and promising treatability results were available, the PeRT wall was included as part of an Interim Record of Decision under Operable Unit III at the MMTS.

The contaminated groundwater flows through a shallow alluvial aquifer that is underlain by impermeable bedrock. The groundwater is naturally funneled through a zone of less than 500 feet. The major contaminants of concern (COCs) at Monticello are arsenic, uranium, vanadium, selenium, lead-210, and manganese.

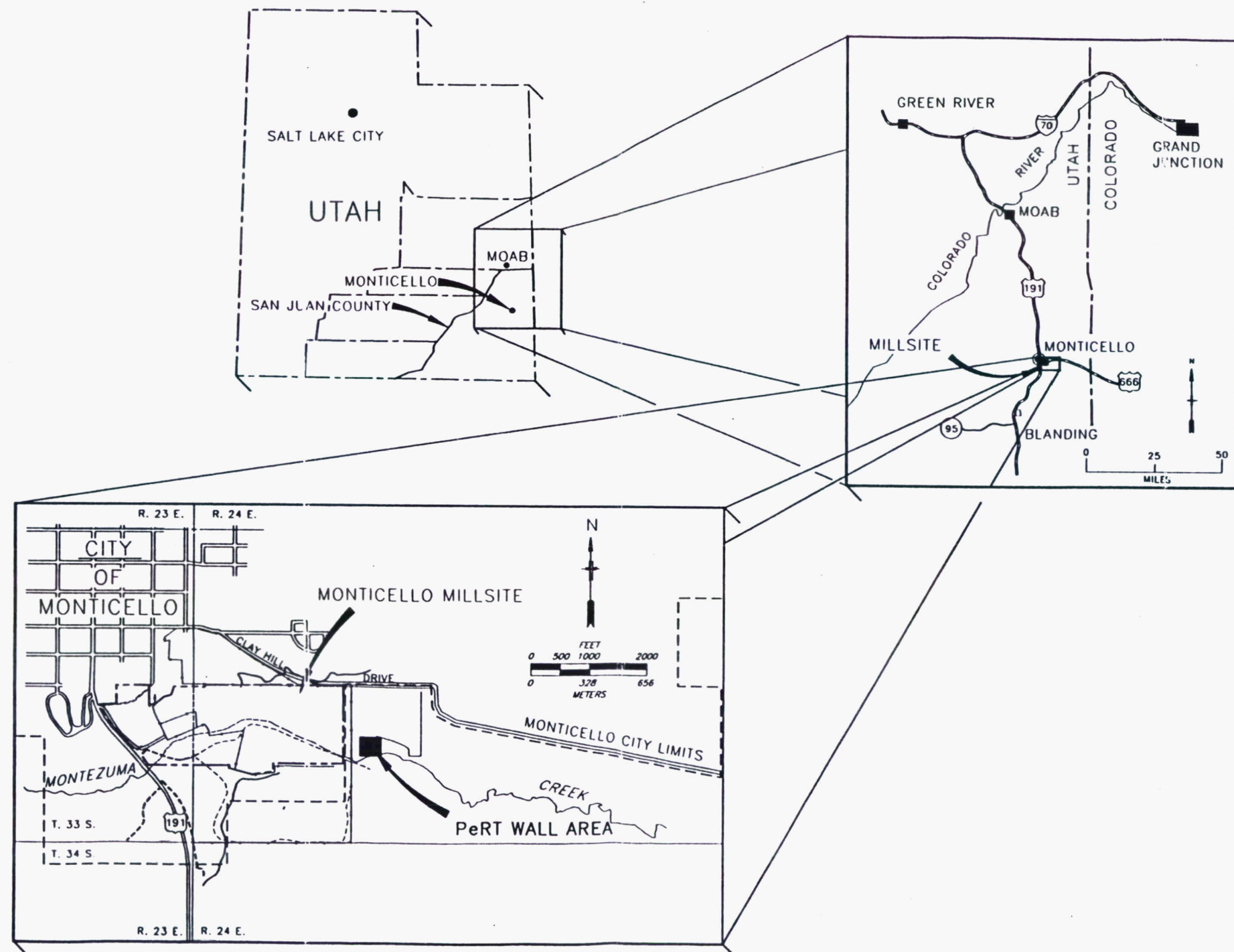
Project Chronology

Table 1.2-1 lists the project chronology for the Monticello Millsite PeRT wall ground water treatment system.

Table 1.2-1 PeRT Wall Project Chronology¹

Activity	Date	Comments
Deployment Plan Completed	11/97	
Initial Review of Designs and Reactive Materials	12/97 – 5/98	Confirmed the use of a funnel and gate system with ZVI as the reactive medium.
Laboratory Treatability Testing	3/98 – 5/98	Tested 28 potential reactive materials in batch and columns tests.
Detailed Design Specifications Developed	5/98 – 12/98	Adjusted design based on regulatory input, engineering considerations, and requirements associated with ongoing soils remediation.
Field Treatability Tests	6/98 – 11/98	Field column testing of most promising reactive materials.
Request for Proposal (RFP) Solicited	12/22/98	Numerous construction requirements based on landholder and regulatory input.
Subcontract Awarded	3/15/99	Awarded to IT Corporation.
Construction Start	05/19/99	Mobilized personnel, equipment, and material. Prepared site for slurry wall construction.
Complete North Slurry Wall	05/26/99	Length = 103 feet. Width = 3.36 feet at the narrowest point. Depth = 10 to 15.5 feet. Depth keyed into bedrock = 0.5 feet to 4.5 feet at refusal.
Complete South Slurry Wall	05/30/99	Length = 240.21 feet. Width = 4.66 feet at narrowest point. Depth = 12 to 16 feet. Depth keyed into bedrock = 1.5 feet to 3.5 feet at refusal.
Installation of Sheet Piling Complete	06/15/99	Completed piling at the south wall. Piling was driven approximately 14 to 16 feet deep at the south end of the wall. The sheet pile box is approximately 103.39 feet long by 7.67 feet wide assuming an average depth of the Z sheet pile.
Complete Installation of Beams and Cross Bracing	06/18/99	Sheet pile box was ready for excavation.
Excavate Sheet Pile Box and Key into Bedrock	06/20/99 06/21/99	Excavated to top of bedrock. Cleaned sides of sheet piling. Keyed (excavated) into bedrock generally at least one-foot deep. Depth from the top of sheet pile to the bottom of key is 11 to 13 feet.
Final Lift of ZVI/Gravel Packs Placed	06/29/99	Top of the PeRT wall is at elevation 6,793.3.
Sheet Piling Pulled from the 100 Foot Upgradient and Downgradient Sides of the PeRT Wall	06/29/99	The sheet piling from the 100-foot upgradient and downgradient sides of the sheet pile box was pulled and transported off the site. Contaminated ground water is flowing through the ZVI reactive material for treatment.
PeRT Wall Complete	06/30/99	Crane demobilized, geotextile fabric installed over ZVI and gravel packs, concrete poured around air sparging system vertical pipes, backfill at top of PeRT wall started.
Final Demobilization and Backfill	07/01/99 through 07/15/99	Demobilize equipment and excess material. Completed contractually obligated backfill of site. Additional backfill has since been added on top of the PeRT wall by Monticello Programs.
Performance Monitoring Wells Installed	8/99	Completed well installation using a geoprobe.
Initial Sampling	9/99, 10/99, 11/99	Future events will be on a quarterly basis.

¹ Appendix A presents a bibliography of the major reports and documents that have been generated for this project.



M:\PTW\121\0004\K00064AA.DWG 12/08/99 2 30pm J50191

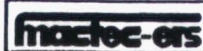
		U.S. DEPARTMENT OF ENERGY GRAND JUNCTION OFFICE GRAND JUNCTION, COLORADO	
PeRT WALL LOCATION MAP			
DATE PREPARED: DECEMBER 8, 1999		FILENAME: K00064AA	

Figure 1-1. PeRT Wall Location Map

2.0 As Built Construction Summary

The PeRT wall was constructed with a permeable reactive gate and impermeable funnel walls. The permeable reactive gate was constructed by driving steel sheet piling down into the bedrock forming a rectangular box 103.39 feet long by 7.67 feet wide. The native soils inside the box were excavated and removed down to a minimum of 1 foot deep (keyed) into the bedrock aquitard. The excavated soils from inside the box were replaced with a reactive medium (-8/+20 mesh ZVI) and gravel packs upgradient and downgradient of the ZVI.

The upstream gravel pack is 1.84 feet wide composed of 13 percent -4/+20 mesh ZVI (by volume) mixed uniformly with ½ inch gravel. The purpose of the upgradient gravel layer is to initiate precipitation in this initial, more permeable zone. Results from the 1998 treatability tests indicate that most precipitation occurs in the first several centimeters of a ZVI barrier. A potential long-term performance issue with PeRT walls is a reduction in hydraulic conductivity from chemical precipitation. Therefore, this unique design feature is intended to extend the longevity of the PeRT wall.

The middle section of the reactive gate contains 100 percent -8/+20 mesh ZVI. Approximately 4,480 cubic feet of ZVI with a loose-filled weight density of 115 pounds per cubic foot were used. The hydraulic conductivity of this material (saturated for 24 hours using a Falling Head Method) is 3.58×10^{-2} centimeters per second. This section of the wall serves as the main treatment area. ZVI dissolution calculations (assuming minimal clogging) indicate that the 4 foot layer of ZVI at Monticello will last more than 100 years.

The downstream gravel pack is 1.84 feet wide, composed of ½ inch gravel and includes an air sparging system constructed of perforated polyvinyl-chloride pipe. Data from the treatability study indicate that iron and manganese may be released from the PeRT wall and become mobile in the ground water. If required, the air sparging system may be used to help precipitate iron and manganese. The field treatability study showed that active aeration of ground water greatly reduces concentration of iron and manganese in solution. It is anticipated, but has not yet been demonstrated, that the iron and manganese will precipitate out of solution as the treated ground water migrates through the aquifer downgradient of the PeRT wall and will therefore not present an unacceptably elevated risk.

The purpose of the impermeable walls is to funnel contaminated ground water to the reactive gate for treatment. The south impermeable funnel wall is 240.21 feet in length and the north funnel wall is 97 feet in length. The impermeable funnel walls were installed using a slurry wall construction method. The bentonite content of the soil/bentonite mix is 4 percent.

After the reactive materials and gravel were placed in the box, the sheet pilings perpendicular to the ground-water flow were removed (two 103.39-foot sections) to allow ground water to flow through the reactive portion of the wall.

This page intentionally blank

3.0 Construction

This section presents a summary of the construction activities and costs for the PeRT wall deployment. The construction activities are reviewed in chronological order with highlights, methodology, specifications, and notes relating to dates and activities. Costs are presented for materials and activities with related notes. In addition, several areas of concern are identified and presented as lessons learned that should be considered for future deployment projects. Plates 1 and 2 (included in pockets on the inside back cover) show the as-built drawings of the completed PeRT wall.

3.1 Description of Activities

Table 3.1-1 lists a summary of activities for the PeRT wall deployment at Monticello, Utah.

3.2 Construction Costs

Table 3.2-1 lists a summary of construction costs for PeRT wall deployment.

Table 3.2-1 PeRT Wall Construction Costs

Description	Cost	Notes
Zero Valent Iron	\$143,800	Includes pretreatment ZVI and all shipping costs.
Mobilization/Demobilization	\$85,900	Some local equipment was used.
Install Slurry Wall	\$80,100	Includes material costs.
Install/Remove Sheet Piling	\$298,600	Credit provided for the removed sheet piling.
Temporary Facilities	\$41,800	Mostly construction trailer costs for 5 weeks.
Site Preparation/Grading	\$18,000	Regrade site area, construction culvert, bentonite removal.
Excavate/Dewater Reactive Gate	\$41,900	Excavate native material and dewater before placement of ZVI and gravel.
Install Reactive Gate	\$80,000	Includes air sparging pipe and geotextile.
Miscellaneous Construction Items	\$35,100	Road maintenance, downtime, backfill trench.
Construction Oversight	\$44,600	MACTEC construction and technical oversight, Health and Safety.
Overhead/G&A/Fee	\$116,800	Applies to all labor and subcontracts
Total Direct Construction Cost	\$986,600	

3.3 Lessons Learned

The Monticello PeRT wall team identified several areas of concern that should be considered during the planning stages for future permeable reactive barrier projects. The following lessons learned may help avoid issues that could cause schedule delays and add additional cost to the installation of a PeRT wall.

- Communicate with local, state, and federal regulators at the project inception. Follow through the duration of the project with detailed regularly scheduled communication to establish an open cooperative working relationship.
- If practical, excavate test trenches and/or holes to evaluate and understand the soil conditions that will be encountered while driving the sheet pile, trenching the slurry wall, and excavating the sheet pile box.
- Obtain sufficient characterization information to aid in the design of the PeRT wall. This includes depth to bedrock at numerous points, groundwater flow rate, contaminant concentrations, several cores from the top of bedrock, seasonal groundwater fluctuation data, hydraulic conductivity of the contaminated aquifer, and clay content of the native materials (to understand the potential for smearing from sheet pile driving).
- The percentage of bentonite required for the soil/bentonite backfill mix should be determined prior to the bid process by testing a representative sample of the soil with at least two different bentonite to slurry to soil ratios in a laboratory. The mix ratios will be determined by evaluating the hydraulic conductivity test results from the two mixes. Hydraulic conductivity tests for materials in the 1×10^{-7} cm/sec range can take in excess of 30 days to reach conclusion.
- The following items should be required as submittals in the design specifications when the design package is sent out for solicitation:
 1. QC plan for Slurry Wall/impermeable wall construction
 2. QC plan for sheet pile installation
 3. Excavation plan
 4. Project site layout plan.
 5. Major items to be included in the daily construction activity logs
- Develop a detailed QA Checklist for the Slurry Wall Construction (if slurry walls are used) that the subcontractor must fill out and submit.
- The following daily reports on slurry wall construction should be required submittals (tailor to suit the individual project):
 1. A slurry wall summary log that contains detailed information on the number of batches of backfill and slurry, the quantity of materials used, and the amount of bentonite used on a daily basis.

Table 3.1-1 Construction Activities for the Monticello Millsite PeRT Wall

Activity	Date	Highlights, Methodology, Specifications, and Notes
Construction Start	May 19, 1999 Through May 23, 1999	<p>Highlights: Mobilized personnel, equipment, and material. Constructed the slurry wall soil/bentonite backfill mixing area. South slurry wall area was verified clean by Monticello Program personnel. Partially removed and leveled the hills/de at the south slurry wall area to enable wall emplacement.</p> <p>Methodology and Specifications: The soil/bentonite backfill was mixed in a depression excavated in the ground located adjacent to the north and south slurry walls. A Caterpillar D6 bulldozer was used to excavate the depression, construct the surrounding berm, and mix the soil, bentonite, and slurry together. As the Caterpillar 325B track excavator removed the soil from the trench (slurry wall), the soil was placed in the mixing area. Water/bentonite slurry was pumped into the area to sluice the mix. The bentonite powder was dispensed onto the soil from 2,800 lb. canvas super sacks with a funnel and drawstring release on the bottom of the bag while the bag is suspended from the track excavator. The bentonite content per cubic foot of soil was 4 percent (3 percent dry bentonite powder and 1 percent water/bentonite slurry mix). The mix is agitated using the bulldozer in a back and forth motion. The mixing continues until visual inspection confirms a homogeneous mixture has been created and a slump of 4 to 6 inches has been achieved. (Reference Figure 3.1-1) The water/bentonite slurry was mixed in a water tank and agitated in the tank and through centrifugal pumps. The bentonite content by weight of water was 6 percent (2,500 lbs. of bentonite was mixed with 5,294 gallons of water). The bentonite was added to the tank from super sacks suspended from a forklift.</p> <p>Notes: All phases of the project were surveyed from construction start to completion. Quality Assurance and Quality Control (QA/QC) testing of the soil/bentonite backfill mix and water/bentonite slurry mix was strictly enforced. Bureau of Reclamation representative Karl Justessen performed QA testing and observed installation of the slurry walls for DOE. All soil used for the soil/bentonite backfill was free of large rocks (greater than 6 inches in diameter). Large rocks were separated from the soil with the track excavator. Soil/bentonite mix and water/bentonite slurry ratios were determined by evaluating hydraulic conductivity test results from tests taken on representative samples of the soil using two different bentonite to slurry to soil ratios.</p>
Start North Slurry Wall	May 24, 1999	<p>Highlights: The north slurry wall was excavated from north to south with a Caterpillar 325B track excavator.</p> <p>Methodology: The slurry wall trenches were excavated to the top of bedrock and keyed (excavated) into the bedrock to refusal. The trench was filled (two feet or less from the top of the trench) with the water/bentonite slurry mix (pumped directly from the storage tank) to maintain trench stability, create a bentonite seal or skin on the trench walls, and fill voids between the trench walls and backfill mix (Figure 3.1-2 shows water/bentonite in the south impermeable wall). The soil/bentonite backfill mix was gently pushed into the north slurry wall with the bulldozer or carefully placed in the trench with the track excavator bucket. The north slurry wall was backfilled from north to south displacing the slurry mix into the excavation as the trench excavation continued (Figure 3.1-3 shows the mostly filled north slurry wall and the track excavator backfilling the trench).</p>
First Shipment of Zero Valent Iron (ZVI) Delivered	May 24, 1999	<p>Highlights: Three of fourteen truckloads of ZVI were received.</p> <p>Specifications: The PeRT wall required 4,840 cubic feet of -8/+20 mesh and 250 cubic feet of -4/+20 mesh ZVI.</p>
Complete North Slurry Wall	May 26, 1999	Specifications: Length = 97 feet. Width = 3.36 feet at the narrowest point. Depth = 10 to 15.5 feet. Key Depth = 0.5 feet to 4.5 feet at refusal.
Start South Slurry Wall	May 27, 1999	<p>Highlights: The south slurry wall was excavated from south to north with a Caterpillar 325B track excavator.</p> <p>Methodology: The soil/bentonite backfill mix was trammed to the south slurry wall with a Caterpillar 938 front-end loader and placed in the trench with the track excavator bucket. The south slurry wall was backfilled from south to north displacing the slurry mix into the excavation as the excavation continued (Figure 3.1-2 shows the soil/bentonite backfill started at the south end of the south slurry wall).</p>
Complete South Slurry Wall	May 30, 1999	Specifications: Length = 240.21 feet. Width = 4.66 feet at narrowest point. Depth = 12 to 16 feet. Key Depth = 1.5 feet to 3.5 feet at refusal.
Demobilize Slurry Wall Equipment and Start Backfill	June 1, 1999	Highlights: Backfilled at south slurry wall area and soil/bentonite mix platform. Stockpiled excess soil/bentonite mix for removal from site.
First Shipment of Sheet Piling Delivered	June 3, 1999	<p>Highlights: First load of Hoesch, Type H-1700K, Steel Z Sheet Piling was received.</p> <p>Specifications: Width = 22.64 inches. Height = 13.78 inches. Thickness at the flange and web = 0.375 inches. Weight = 45.23 lbs. per lineal foot and 23.96 lbs. per square foot of wall. Section modulus = 31.62 in.³ per lineal foot of wall. Moment of inertia = 217.88 in.⁴ per lineal foot of wall. Joint type = interlocking single jaw.</p>
Crane and Vibratory Pile Driver/Extractor Arrives at Site	June 4, 1999	Specifications: Crane: 140-Ton FMC Link Belt HC-238A. Driver/Extractor: American Piledriving Equipment Inc., 18,000 lb., 600 hp., Hydraulic. (Reference Figures 3.1-4 and 3.1-5)
Last Shipment of ZVI Delivered to the Site	June 7, 1999	<p>Highlights: Fourteen truckloads of ZVI were delivered.</p> <p>Two truckloads of sheet piling were delivered.</p>
Last Shipment of Sheet Piling Delivered to the Site	June 7, 1999	Highlights: Two truckloads of sheet piling were delivered.
Start Installation of Sheet Piling	June 8, 1999	<p>Highlights: Installation was started at the south end of the north slurry wall and continued with the west and east walls working to the south. (Reference Figures 3.1-4 and 3.1-6)</p> <p>Specifications: Piling was driven approximately 12 to 14 feet deep at the north end of the wall.</p>
Installation of Sheet Piling Complete	June 15, 1999	<p>Highlights: Completed driving the piling at the south wall. (Reference Figure 3.1-6) The excess sheet piling was then cut to a predetermined elevation to facilitate installation of the structural support steel and placement of the treatment system (Figure 3.1-7 shows the sheet pile cut to the predetermined elevation with structural support steel in place).</p> <p>Specifications: Piling was driven approximately 14 to 16 feet deep at the south end of the wall. The sheet pile box is approximately 103.39 feet long by 7.67 feet wide.</p>
Excess Soil/Bentonite Mix Removed From Site	June 15, 1999	Highlights: DOE donated the excess soil/bentonite mix to local property owners to build stock ponds.

Table 3.1-1 Construction Activities for the Monticello Millsite PeRT Wall (continued)

Activity	Date	Highlights, Methodology, Specifications, and Notes
Start Excavation of Sheet Pile Box	June 15, 1999	Methodology: Excavated to a depth of 4 feet to install structural beams and cross bracing.
Start Installation of Structural Support Beams and Cross Bracing	June 16, 1999	Methodology: Installed structural beams and cross bracing to allow excavation of the box to bedrock. (Reference Figure 3.1-7)
Complete Installation of Beams and Cross Bracing	June 18, 1999	Highlights: The sheet pile was box ready for excavation.
Excavate Sheet Pile Box	June 20, 1999	Highlights: Excavated to the top of the bedrock.
Final Clean-up of Sheet Pile Box and Key into Bedrock	June 21, 1999	Highlights: Cleaned remaining soil from the sides of the sheet piling with shovels and scrapers. Keyed (excavated) into the bedrock one foot deep. (Reference Figure 3.1-7) The bedrock is a competent mudstone with minor fracturing in the upper layers. Specifications: Depth from the top of the sheet pile to the bottom of the key was 11 to 13 feet. Notes: After excavation was complete, ground water started seeping into the excavation through the sheet pile joints. (Reference Figure 3.1-7) Before starting this project, water leaking into the excavated sheet pile box was a serious concern. However, the soils from the upgradient Monticello Millsite were remediated prior to construction of the PeRT wall, and as part of this remediation, a large portion of the upgradient aquifer was dewatered or diverted prior to the construction of the PeRT wall. As a result, ground water levels at the PeRT wall were down to approximately 3 feet during construction and posed no immediate concern. Early in the design stages and when the project was sent out for solicitation, the ground water levels were a major concern. Options to manage the ground water were developed and included with the solicitation. Option No. 1 specified the use of Waterloo Barrier Sealable Joint Sheet Piling. The sealant is applied after the piling is driven in the ground. Option No. 2 was to use conventional piling with a hydrophilic single component liquid urethane water stop sealant applied prior to driving. Option No. 3 was to pump the water to a pond on the Millsite where it could be treated and released. Because of decreased water levels, Option 3 was used for this project.
Place Sheet Steel Boxes	June 21, 1999	Methodology: Sheet steel boxes (specifically constructed for this project) were placed on the bedrock to keep the upgradient and downgradient gravel packs and ZVI separate during placement. The 4-foot high steel sheet boxes were constructed from ¼ inch thick steel plate on the sides separated with angle iron 4 feet apart. The sheet steel boxes were open on the top, bottom, and ends. They were constructed in various lengths and welded together to fit the length of the sheet pile box on the inside. As the ZVI and gravel packs were filled to the top of the sheet steel boxes, the boxes were pulled vertically with chain ratchet hoists attached to the structural beams while maintaining the correct separation from the sides of the sheet pile box. The boxes were lifted to the top of the sheet piling as the ZVI and gravel packs were filled to the correct elevation. (Reference Figure 3.1-8) Notes: When the sheet pile box was filled to a precalculated level, the structural beams and cross bracing was removed and placement continued.
Start Placement of -8/+20 mesh ZVI, Downgradient Gravel Pack, and Air Sparging system	June 21, 1999	Methodology: Placed -8/+20 mesh ZVI from Super Sacks suspended from the 140 ton crane. Specifications: Super Sacks are 3,000 lb. canvas bags with a funnel and drawstring release on the bottom of the bag for dispensing. The -8/+20 mesh ZVI was placed 4 feet wide at the center of the wall in the sheet steel box. Methodology: The downgradient gravel pack was placed with a Caterpillar 938 front-end loader down plywood chutes. Specifications: The ½ inch gravel downgradient gravel pack is an average 1 foot 10 inches wide allowing for the Z-shaped height (13.78 inches) of the sheet pile.
Start Placement of -4/+20 mesh ZVI and ½ Inch Gravel Mix for Upgradient Gravel Pack	June 22, 1999	Methodology and Specifications: The -4/+20 mesh ZVI and ½ inch gravel was mixed in a concrete mix truck and placed in the upgradient gravel pack from the truck with the trucks chutes and plywood chutes. Allowing for the Z-shaped height (13.78 inches) of the sheet pile, the average width of the -4/+20 mesh ZVI and ½ inch gravel pack is 1 foot 10 inches. The first 24-inch lift was mixed with 23 percent ZVI by volume and the remaining with 13 percent. (Reference Figure 3.1-8) Notes: Approximately 15 gallons of water was added per truckload to control dust.
Continue Placement of ZVI, Gravel Packs, and Air Sparging System	June 23, 1999 Through June 28, 1999	Specifications: The outside edge of the air sparging system horizontal feed pipe is located 2 inches inside the exterior face of the downgradient gravel pack and approximately 1-foot above the bottom of the excavation. The air sparging system pressure relief vent piping is also installed 2 inches inside the exterior face of the downgradient gravel pack. Otherwise the installation is as designed. Notes: The air sparging pipe was placed as far downgradient as possible to minimize interaction of the oxidation environment of an air sparging system (if it is used) with the strongly reducing environment of the ZVI.
Sheet Piling Cutoffs Removed from the Site	June 26, 1999	Highlights: DOE donated the sheet piling cutoffs to a local property owner.
Final Lift of Sheet Steel Boxes	June 28, 1999	Highlights: The sheet steel boxes were lifted into their final position to place the last layer of ZVI and gravel packs. After the material was placed, the steel boxes were removed from the PeRT wall.
Final Lift of ZVI/Gravel Packs Placed	June 29, 1999	Specifications: Top of the PeRT wall is at elevation 6,793.3.
Sheet Piling Pulled from the 103.39-Foot Upgradient and Downgradient Sides of the PeRT Wall	June 29, 1999	Highlights: The sheet piling from the 103.39-foot long upgradient and downgradient sides of the sheet pile box was pulled and transported off the site. Contaminated ground water is now flowing through the ZVI reactive material for treatment.
PeRT Wall Complete	June 30, 1999	Highlights: The crane was demobilized, geotextile fabric was installed over the ZVI and gravel packs, concrete was poured around the air sparging system vertical pipes, and backfill was started at the top of the PeRT wall (Figure 3.1-9 shows the geotextile fabric covering the ZVI and gravel packs and the air sparging system relief vent pipes and feed pipe [foreground], which are exposed 6-feet above the top of the wall after construction). The bases of the pipes are protected with a 6" x 2' x 2' concrete pad. After the final finish grade and backfill were complete, the feed and vent pipes were cut off and capped.
Final Demobilization and Backfill	July 1, 1999 Through July 15, 1999	Highlights: Demobilize personnel, equipment, and material. Backfill site. Final clean up of site.



Figure 3.1-1. Mixing and Placing Soil/Bentonite Backfill for the North Slurry Wall



Figure 3.1-3. Placing Soil/Bentonite Backfill in the North Slurry Wall Trench
(Note the super sack of bentonite suspended from the Gradall forklift. Placing bentonite in the water/bentonite slurry mixing tank)

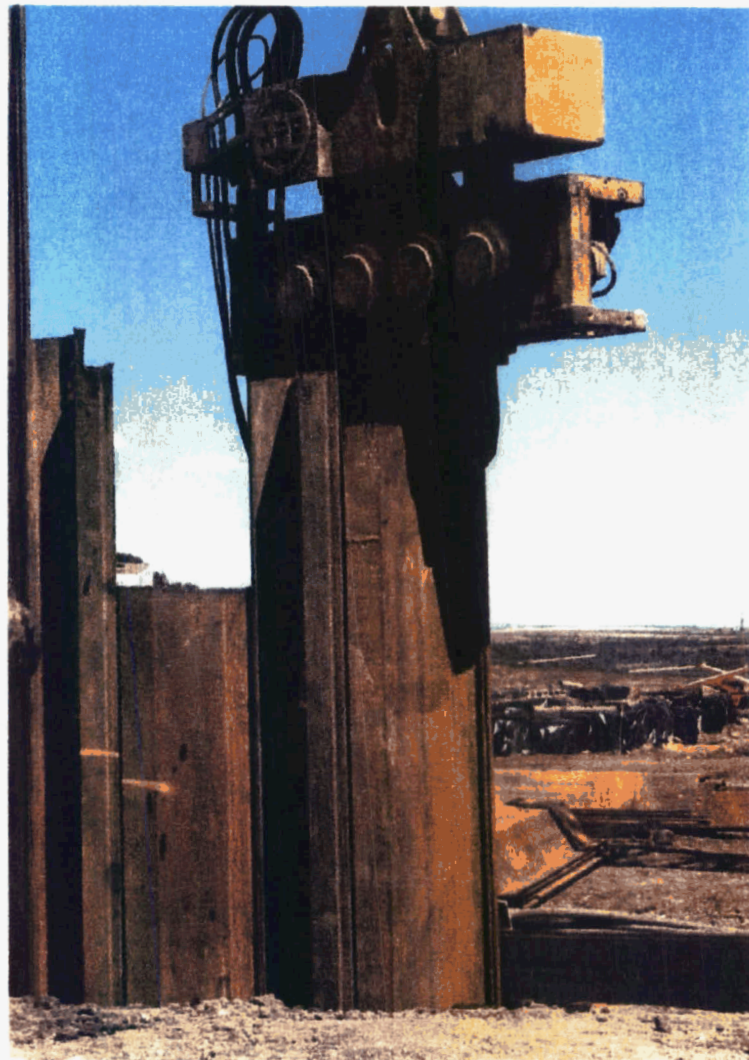


Figure 3.1-5. Vibratory Driver/Extractor Installing Sheet Pilings



Figure 3.1-6. Sheet Pile Box Looking North to South

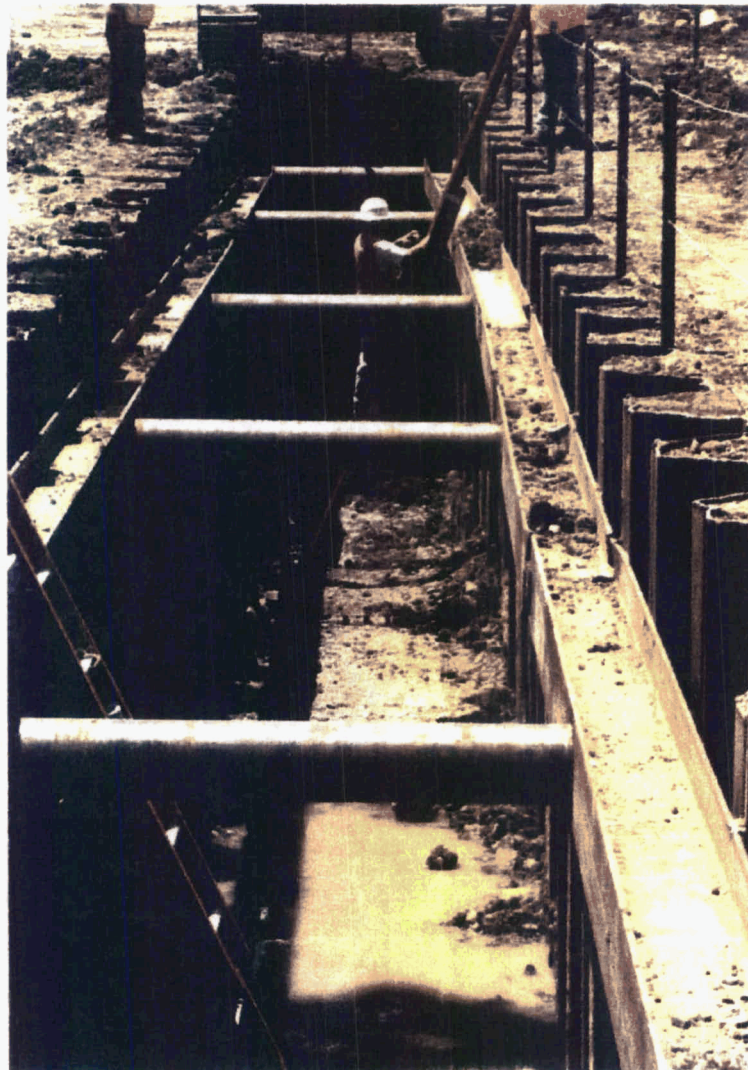


Figure 3.1-7. Sheet Pile Box With Structural beams and Cross bracing in Place
(Excavation complete to the bottom of the key in the bedrock. Note the groundwater that has seeped through the sheet piling at the bottom of the excavation.)



Figure 3.1-8. Installation of Reactive Materials at Center 4 Feet of -8/+20 ZVI
(At right, 1'-10" average width of -4/+20 ZVI and ½ inch gravel mix for upgradient gravel pack. Not visible, at left, 1'-10" average ½ inch downgradient gravel pack. Note the 4-foot deep and 4-foot wide sheet steel box used to contain the -8/+20 ZVI and separate the gravel packs.)



Figure 3.1-9. Completed Wall Covered with Geotextile Fabric
(Air sparging system piping 6-foot above completed wall. Backfill is started and forms for the piping concrete protective base and are being set.)

2. An elevation sketch on graph paper showing:
 - A. Length of daily excavation and backfill.
 - B. Station numbers and existing grade.
 - C. Depth to top of daily backfill at each station.
 - D. Depth to bottom of keyed excavation at each station.
 - E. Calculations showing quantity of daily total excavation, backfill, and open excavation filled with slurry.
 3. Slurry Test Data for Mixed Slurry and Trench Slurry that includes data on viscosity, density, and filtrate loss.
 4. Backfill test data including slump and density information.
 5. Detail excavation measurements that can be used to generate as-builts.
- If the project site or adjacent sites require remediation, schedule permeable reactive barrier work to take place after remediation is complete.
 - When designing the slurry wall consider initial setting (1 foot plus or minus within the first few days) and consolidation settling (a few inches in the first year).

This page intentionally blank

4.0 Performance Monitoring

An extensive monitoring network was installed during the summer of 1999 to evaluate the performance of the PeRT wall. Figure 4-1 shows the locations of the performance monitoring wells. To date, three sampling rounds have been completed (September, October, and November 1999). The next round of sampling will occur in January in conjunction with the quarterly Monticello Operable Unit III sampling. All additional sampling will be done on a quarterly basis with the last sampling event for the ASTD project scheduled for July 2001 (the Monticello Operable Unit III program will continue the sampling after the ASTD sampling is complete).

Results from the first round of sampling are available (results from the second two rounds will be available shortly). The data from the first sampling round is presented in Table 4-1. The data for arsenic, iron, manganese, molybdenum, nitrate, selenium, uranium, and vanadium are shown in Figures 4-2 through 4-9. Overall, the PeRT wall has been very effective in reducing the contaminant concentrations. Concentrations of arsenic, selenium, uranium, and vanadium have been reduced to nondetectable levels within the wall. In addition, concentrations of molybdenum and nitrate are reduced to near nondetectable levels. In some cases, these concentrations begin to increase because the clean water exiting the wall is leaching contamination from the native materials. As expected, concentrations of iron and manganese (a trace contaminant in ZVI) increase as groundwater passes through the wall. Concentrations of iron exiting the wall are lower than expected (based on the treatability studies) and are well within acceptable risk ranges. Although the concentrations of manganese are elevated, they should decrease over time (based on the treatability work) as more groundwater passes through the wall. Manganese concentrations exiting the PeRT wall and downgradient of the wall will be carefully tracked over the next several sampling events. If necessary, these concentrations can be reduced using the air sparging system that was installed in the downgradient gravel pack.

Water levels were also measured and plotted. These water level measurements are still inconclusive in large part because of ongoing remediation (including dewatering) that is occurring just upgradient of the PeRT wall. However, there does appear to be some mounding (as expected) that is occurring upgradient of the wall. This situation will be observed over time as the system reaches equilibrium.

This page intentionally blank

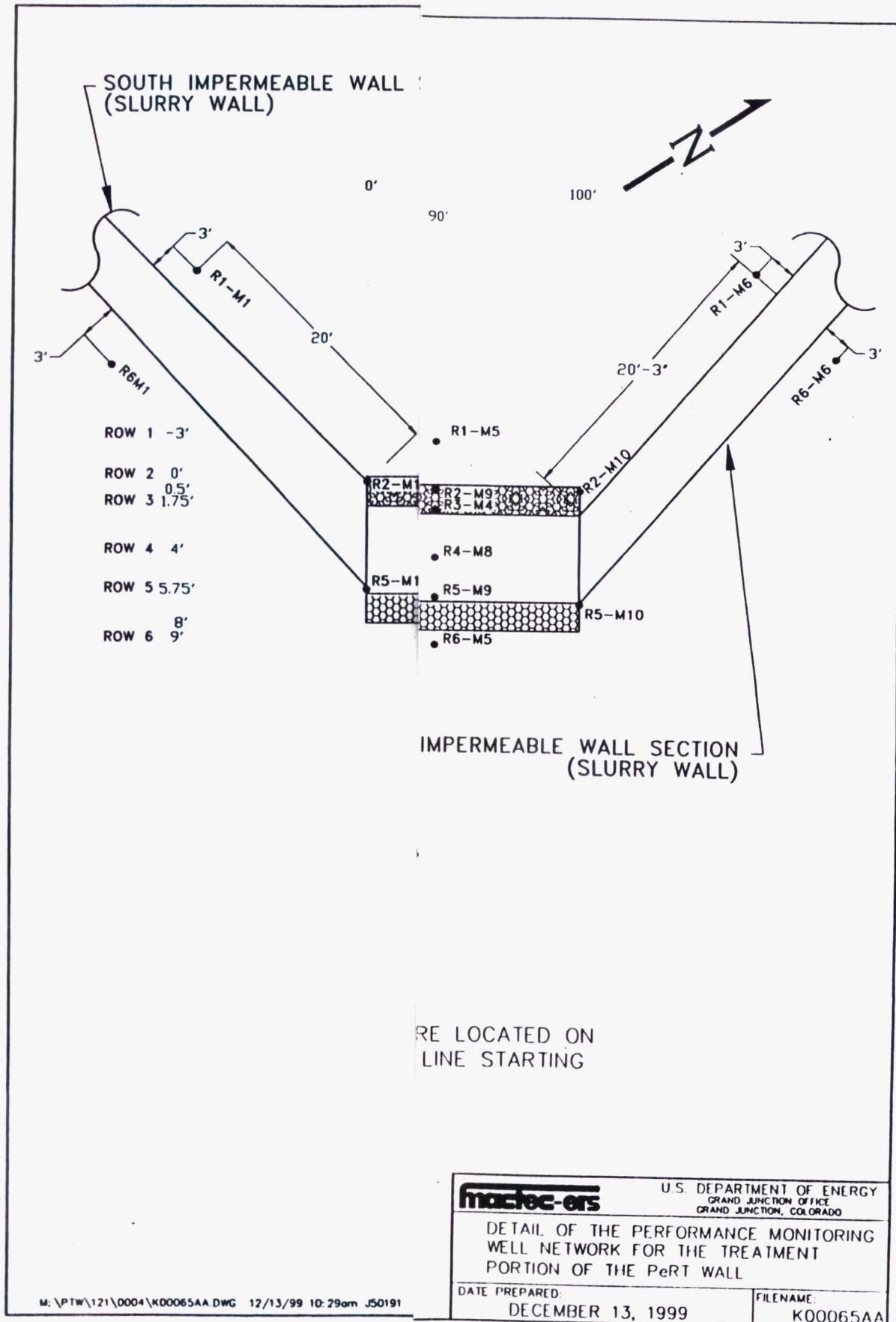


Table 4-1 PeRT Wall Sampling Data—September 1999

WELL ID	X (ft)	Y (ft)	Duplicate	CaCO ₃ mg/L	As µg/L	Br µg/L	Ca µg/L	CDT µmhos/cm	Cl µg/L	DO mg/L	Fe µg/L	K µg/L	Mg µg/L	Mn µg/L	Mo µg/L	Na µg/L	NO ₃ µg/L	ORP mV	pH	Ra226 pCi/L	Se µg/L	SO ₄ µg/L	Temp deg C	U µg/L	V µg/L
R1-M1	23997.72	10240.47		298	11.4		329000	3380		0.33	<9.0	26600	84600	872	91.1	345000		194	6.59		14.7		15.9	739	430
R1-M2	24013.37	10265.13		246	10.0	633	350000	3400	140000	0.59	<9.0	24700	90800	596	76.3	351000	107000	-14	6.61	0.35	17.5	1200000	16.7	680	428
R1-M3	24024.28	10281.69		249	10.0	650	339000	3400	134000	0.43	<9.0	21800	88000	608	67.5	347000	114000	211	6.72		14.9	1190000	15.9	483	387
R1-M4	24046.85	10314.80		369	~7.9	680		3370	173000	0.26					~42.3		71100	-100	6.53		51.8	1250000	15.4	584	353
R1-M5	24056.31	10332.06		321	~7.2			3200		0.92					~49.1			-121	6.64	0.25	54.6		17.5	566	339
R2-M1	24011.51	10254.27		25	<0.40		214000	2950		0.28	2070	16600	58300	613	~18.0	331000		-368	8.54		~0.30		18.7	<0.20	<1.0
R2-M2	24017.22	10262.85		55	<0.40	640	189000	2830	146000	0.17	5190	17400	82200	879	~16.0	334000	~110	-331	8.19		~2.0	1100000	16.7	~1.8	<1.0
R2-M3	24022.55	10271.01		104	<0.40		224000	2980		0.21	6220	17600	79300	1000	~16.6	324000		-285	7.74		~6.9		17.4	9.3	<1.0
R2-M4	24028.06	10279.23		42	<0.40	665	214000	2900	151000	0.18	3330	13900	69800	667	~18.8	320000	9550	-271	8.27		~0.48	1140000	16.9	~0.56	<1.0
R2-M5	24033.78	10287.63		61	<0.40		204000	2850		0.26	9990	14600	77300	1650	~14.7	325000		-288	7.92		~0.93		16.7	<0.20	<1.0
R2-M6	24044.89	10303.86		333	<0.40			3380		0.88					52.4			-86	6.60		27.4		14.7	444	~15.0
R2-M7	24050.68	10312.26		380	<0.40	672		3350	163000	0.49					~22.2		30100	-179	6.82		14.9	1240000	16.1	173	<1.0
R2-M8	24056.42	10320.49		342	<0.40			3220		0.11					~8.4			-280	7.34		~2.1		15.9	~0.82	<1.0
R2-M9	24061.92	10328.49		186	<0.40			3300		0.23					~5.4			-265	7.29		~0.13		16.9	~0.31	<1.0
R2-M10	24067.89	10336.83		63	<0.40			2830		0.69					~9.2			-232	7.60		<0.10		17.6	<0.20	<1.0
R3-M1	24017.83	10262.39		59	<0.40	612	176000	2840	138000	0.16	5430	17700	84400	1550	~9.9	330000	~26.1	-345	8.09		~0.21	1070000	16.8	<0.20	<1.0
R3-M2	24028.82	10278.74		33	<0.40	728	206000	2880	161000	0.17	2310	14700	72100	700	~16.1	326000	1980	-361	8.64		<0.10	1180000	17.1	<0.20	<1.0
R3-M3	24051.42	10311.76		398	<0.40	661		3360	161000	0.70					~32.3		54500	-153	6.76		27.5	1230000	15.7	278	<1.0
R3-M4	24062.69	10328.19		168	<0.40			3030		0.20					~2.4			-278	7.27		<0.10		16.8	<0.20	<1.0
R4-M1	24019.76	10260.87		12	<0.40	648	179000	2860	144000	0.10	149	18900	83900	1050	~1.9	333000	~30.6	-398	9.29		<0.10	1110000	16.7	<0.20	<1.0
R4-M2	24025.31	10269.09		8	<0.40		174000	2850		0.22	950	18400	80400	1120	~5.0	325000		-381	8.69		<0.10		17.4	<0.20	<1.0
R4-M3	24030.85	10277.40		15	<0.40	705	205000	2840	159000	0.25	~85.3	14100	71900	392	~3.3	320000	~13.4	-371	9.83		<0.10	1180000	17.4	<0.20	<1.0
R4-M4	24036.38	10285.64		17	<0.40		166000	2700		0.32	162	15000	69200	717	~3.8	324000		-337	9.62		<0.10		16.8	<0.20	<1.0
R4-M5	24047.67	10302.03		186	<0.40			3070		0.10					~3.7			-288	7.41		<0.10		14.9	<0.20	<1.0
R4-M6	24053.39	10310.50		50	<0.40	670		2980	160000	0.00					~2.5		572	-337	8.07		<0.10	1210000	15.4	<0.20	<1.0
R4-M7	24059.05	10318.69		24	<0.40			2890		0.44					~5.7			-336	9.00		<0.10		15.9	<0.20	<1.0
R4-M8	24064.88	10326.81		41	<0.40			2770		0.35					~2.4			-321	9.39		<0.10		16.5	<0.20	<1.0
R5-M1	24015.39	10251.80		27	<0.40		220000	3060		0.26	153	16700	66200	377	~2.2	338000		-4	9.41		<0.10		18.3	<0.20	<1.0
R5-M2	24020.70	10260.31		9	<0.40	645	182000	2870	147000	0.18	178	18900	84100	789	~1.4	330000	~15.1	-385	9.34	0.15	<0.10	1170000	17.1	<0.20	<1.0
R5-M3	24026.29	10268.34		2	<0.40		186000	2850		0.17	230	18600	80400	307	~2.1	327000		-358	9.24		<0.10		17.3	<0.20	<1.0
R5-M4	24032.11	10276.55		22	<0.40	697	211000	2840	162000	0.16	169	14200	66700	390	~3.0	319000	<10.0	-388	9.82		<0.10	1160000	17.4	<0.20	<1.0
R5-M5	24037.70	10284.76		11	<0.40		171000	2740		0.20	127	14400	73400	588	~2.4	313000		-416	9.68		<0.10		17.2	<0.20	<1.0
R5-M6	24048.92	10301.32		82	<0.40			2910		0.19					~4.6			-250	7.43		<0.10		15.2	<0.20	<1.0
R5-M7	24054.67	10309.51		32	<0.40	683		2940	162000	0.02					~2.0		275	-345	7.49		<0.10	1220000	15.2	<0.20	<1.0
R5-M8	24060.37	10317.72		34	<0.40			2910		0.07					~3.0			-357	9.13		<0.10		16.2	<0.20	<1.0
R5-M9	24066.10	10325.94		35	<0.40			2880		0.50					~4.3			-293	9.44	0.48	<0.10		16.1	<0.20	<1.0
R5-M10	24071.81	10334.16		61	<0.40			2850		0.78					~12.3			-204	9.25		<0.10		18.8	~0.33	<1.0
R6-M2	24024.41	10257.45		2	~2.7	653	206000	2910	149000	0.17	~22.4	17600	75900	1470	~7.7	338000	~17.7	-269	8.93		<0.10	1150000	17.7	<0.20	~3.0
R6-M3	24035.76	10274.01			~1.0		324000				~44.8	21200	72800	3420	121	253000					~1.1			368	~25.1
R6-M4	24058.24	10307.01		52	~7.1	675		2820	160000	0.92	279			3330	~30.7		414	-134	6.85		<0.10	1130000	15.5	~2.4	~14.7
R6-M5	24069.65	10323.58		57	~4.7			2830		0.75	153			6090	~35.3			-260	8.20		<0.10		15.9	8.4	~2.7
R7-M1	24040.97	10246.55			~2.0		284000				~40.2	24500	71400	4160	141	340000					~2.0			495	90.7
R9-M1	24078.81	10254.30			~0.69		282000				<9.0	17100	69000	1660	63.6	313000					~1.6			76.9	~28.3
R10-M1	24097.94	10258.15			~3.4		260000				~12.0	13700	72400	797	52.0	309000					~0.70			22.2	154
R11-M1	24118.49	10262.65			<0.40		345000				~36.9	14900	84500	3170	98.8	312000					~1.5			152	~30.2
T1-D	24035.20	10297.77		295	~9.9	640		3240	141000	0.30	~15.2			289	63.4		111000	-34	6.48		17.6	1230000	15.0	468	363
T1-D	24035.20	10297.77	1		10.0	661			141000		~11.8			293	67.0		110000				17.6	1230000		518	362
T1-S	24036.07	10299.04		279	~9.8	664		3190	143000	0.68	<9.0			53.0	52.0		113000	-29	6.48		17.0	1240000	16.4	431	370
T2-D	24038.58	10295.63		277	<0.40	675		3100	148000	0.13	13400			622	~21.8		14900	-214	7.31		~8.4	1220000	16.5	27.5	<1.0
T2-S	24039.49	10296.60		59	<0.40	669		2730	151000	0.01	3730			250	~45.5		4010	-318	8.03		~2.0	1080000	17.4	7.6	<1.0
T3-D	24039.58	10294.69		283	~0.44	657		3300	146000	0.01	35300			749	~6.8		~67.2	-243	7.34		~2.0	1180000	16.9	~0.50	<1.0
T3-S	24040.45	10295.74		43	<0.40	633		2690	149000	0.02	~54.3			141	~48.1		~126	-265	9.31		<0.10	1020000	17.0	<0.20	<1.0
T4-D	24041.63	10293.42		36	<0.40	638		2770	151000	0.00	188			270	~4.8		~28.4	-273	8.73		<0.10	1100000	16.6	<0.20	<1.0
T4-D	24041.63	10293.42	1		<0.40	647			157000		303			272	~3.8		~51.8				<0.10	1130000		<0.20	<1.0
T4-S	24042.53	10294.49		14	<0.40	748		2660	156000	~0.04	195			562	~30.7		~22.1	-295	8.92		<0.10	1020000	17.3	<0.20	<1.0
T4-S	24042.53	10294.49	1		<0.40	671			154000		~94.0			525	~31.0		~54.0				<0.10	1020000		<0.20	<1.0
T5-D	24042.73	10292.64		22	<0.40	70																			

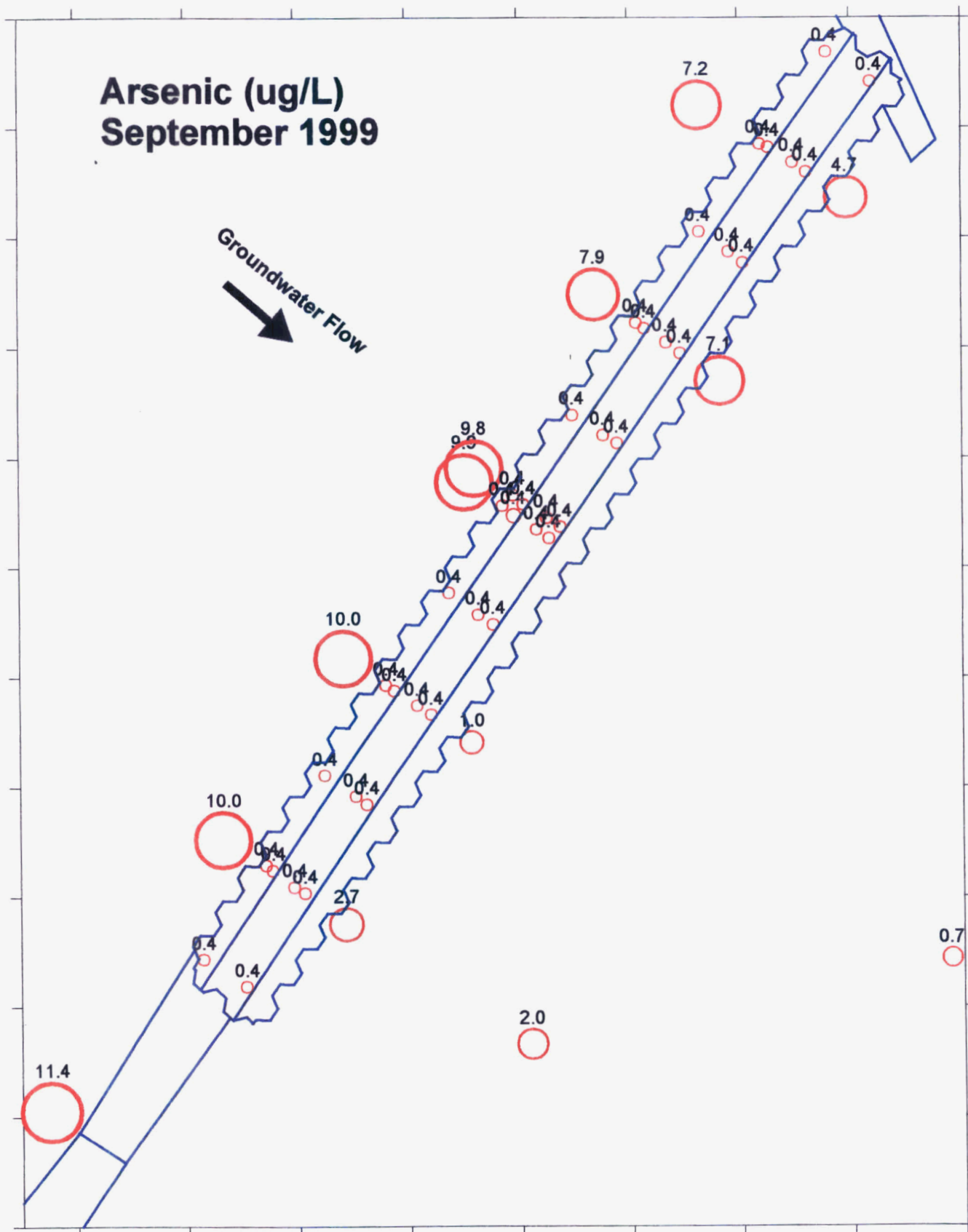


Figure 4–2. Arsenic Sampling Data

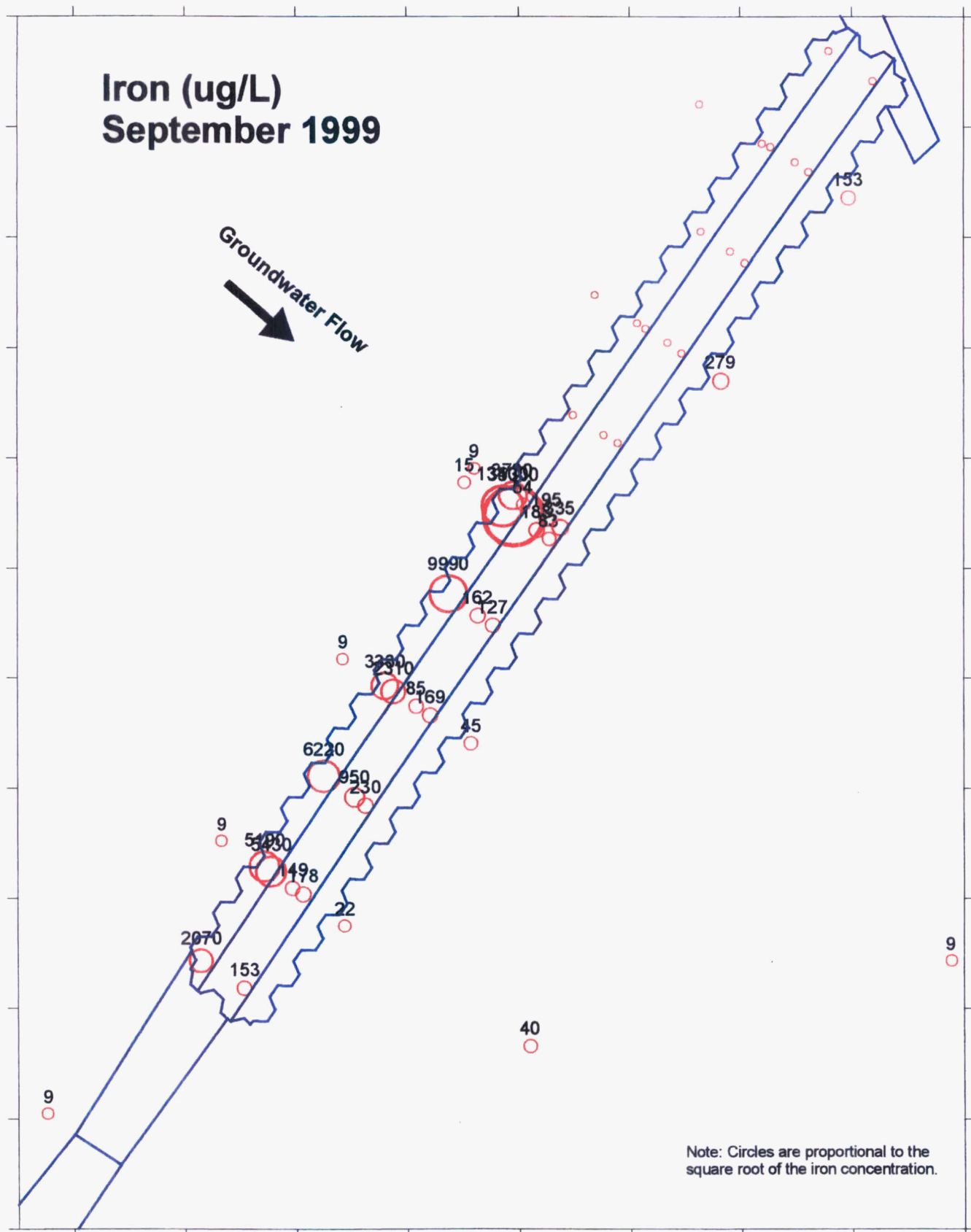


Figure 4-3. Iron Sampling Data

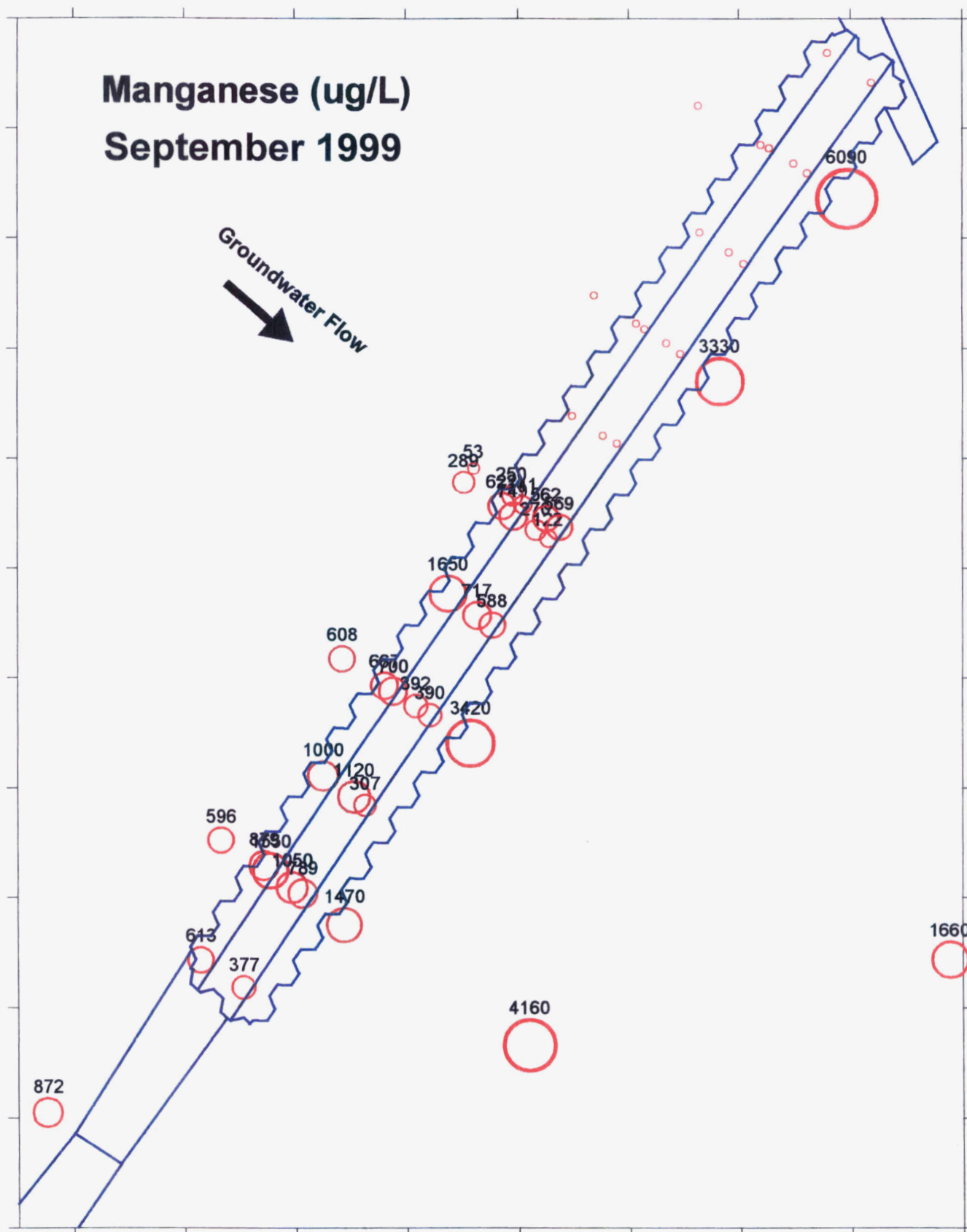


Figure 4-4. Manganese Sampling Data

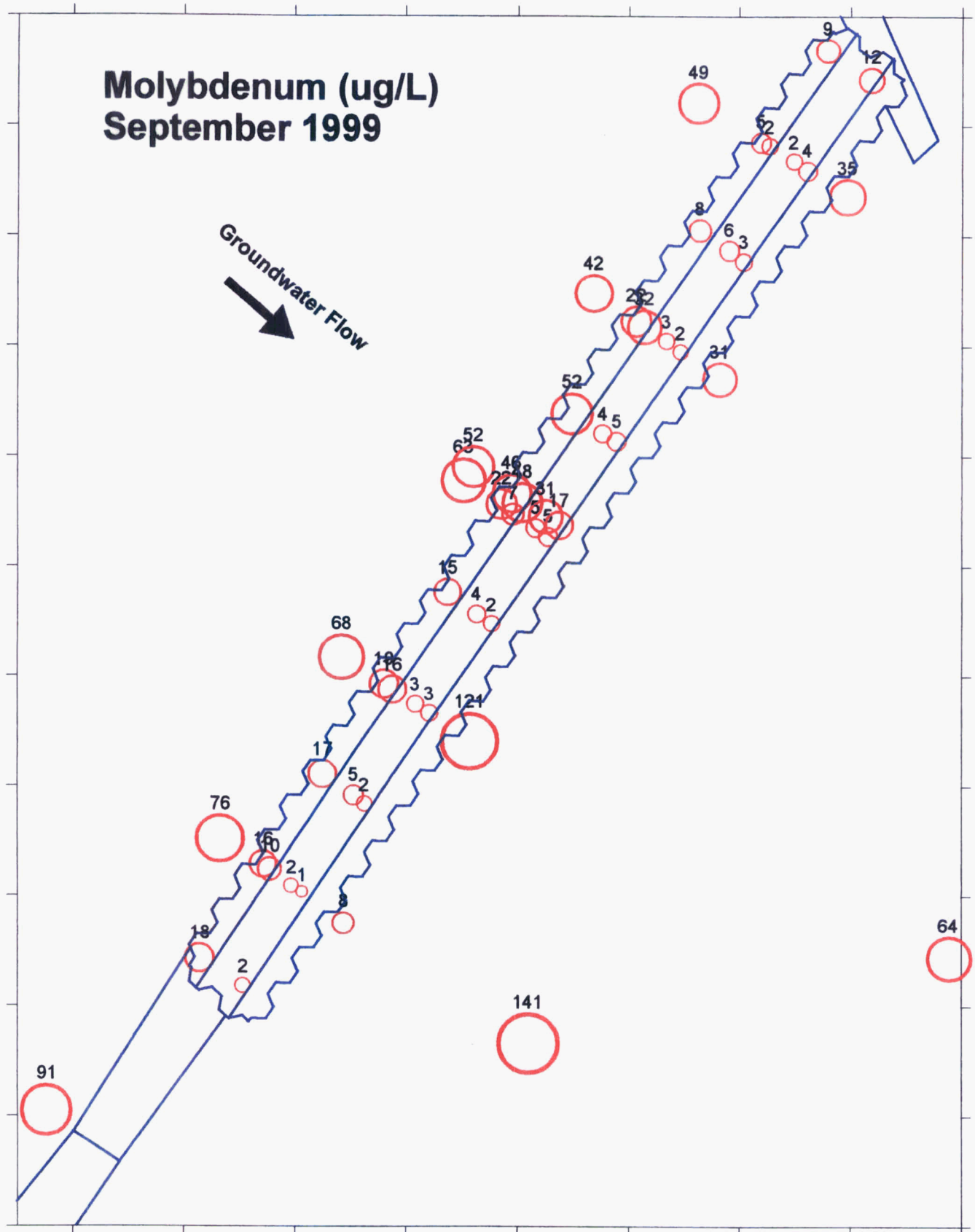


Figure 4-5. Molybdenum Sampling Data

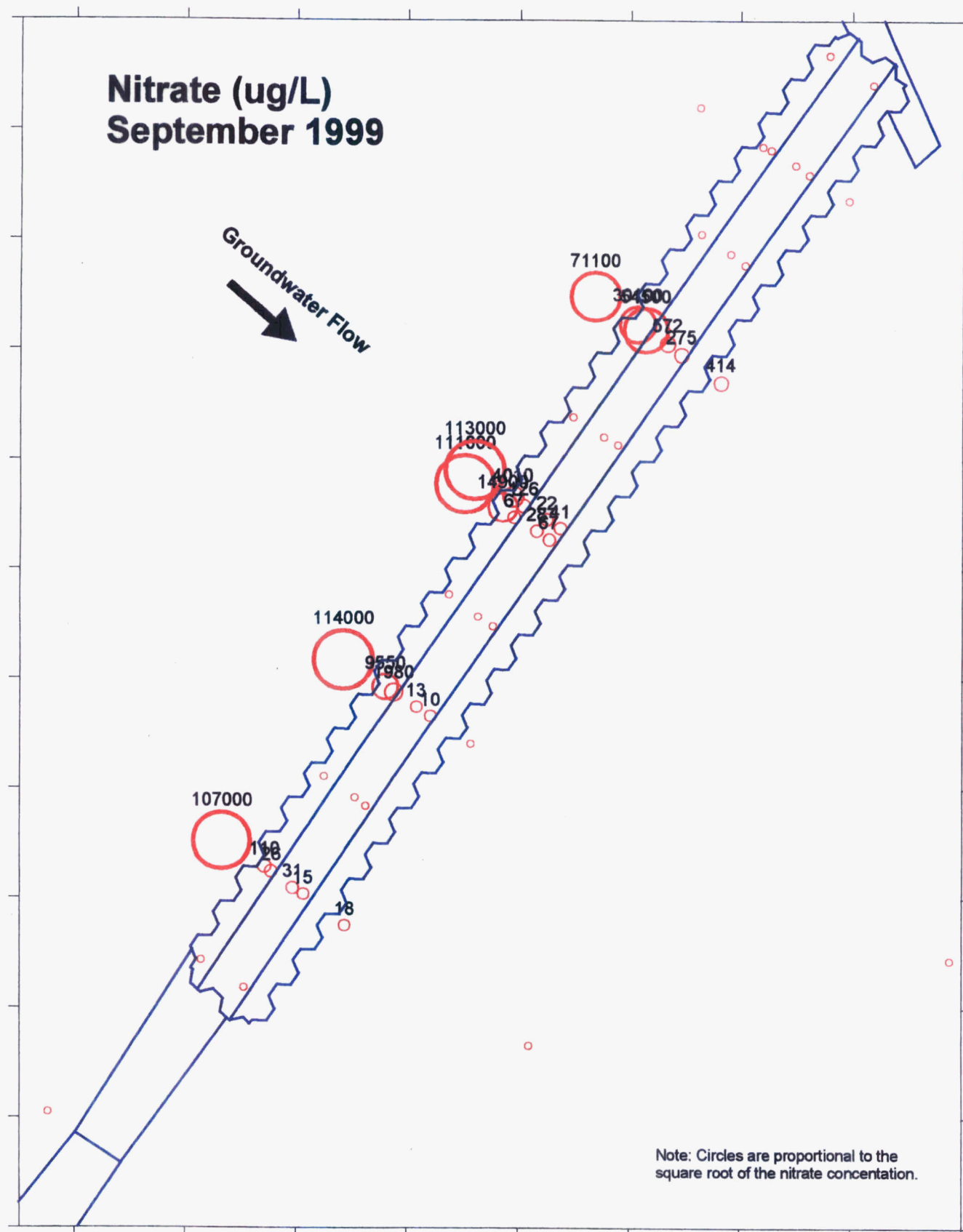


Figure 4-6. Nitrate Sampling Data

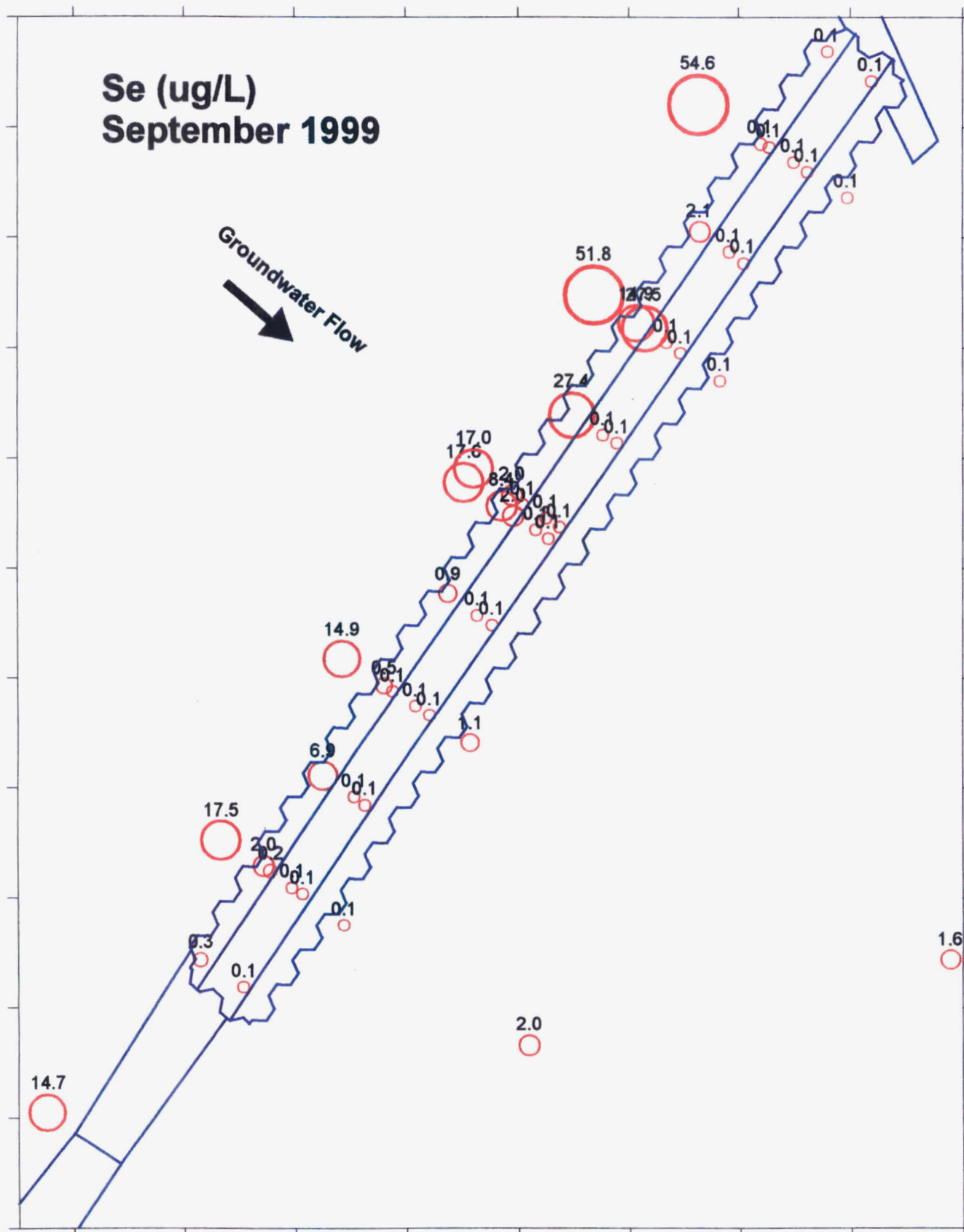


Figure 4-7. Selenium Sampling Data

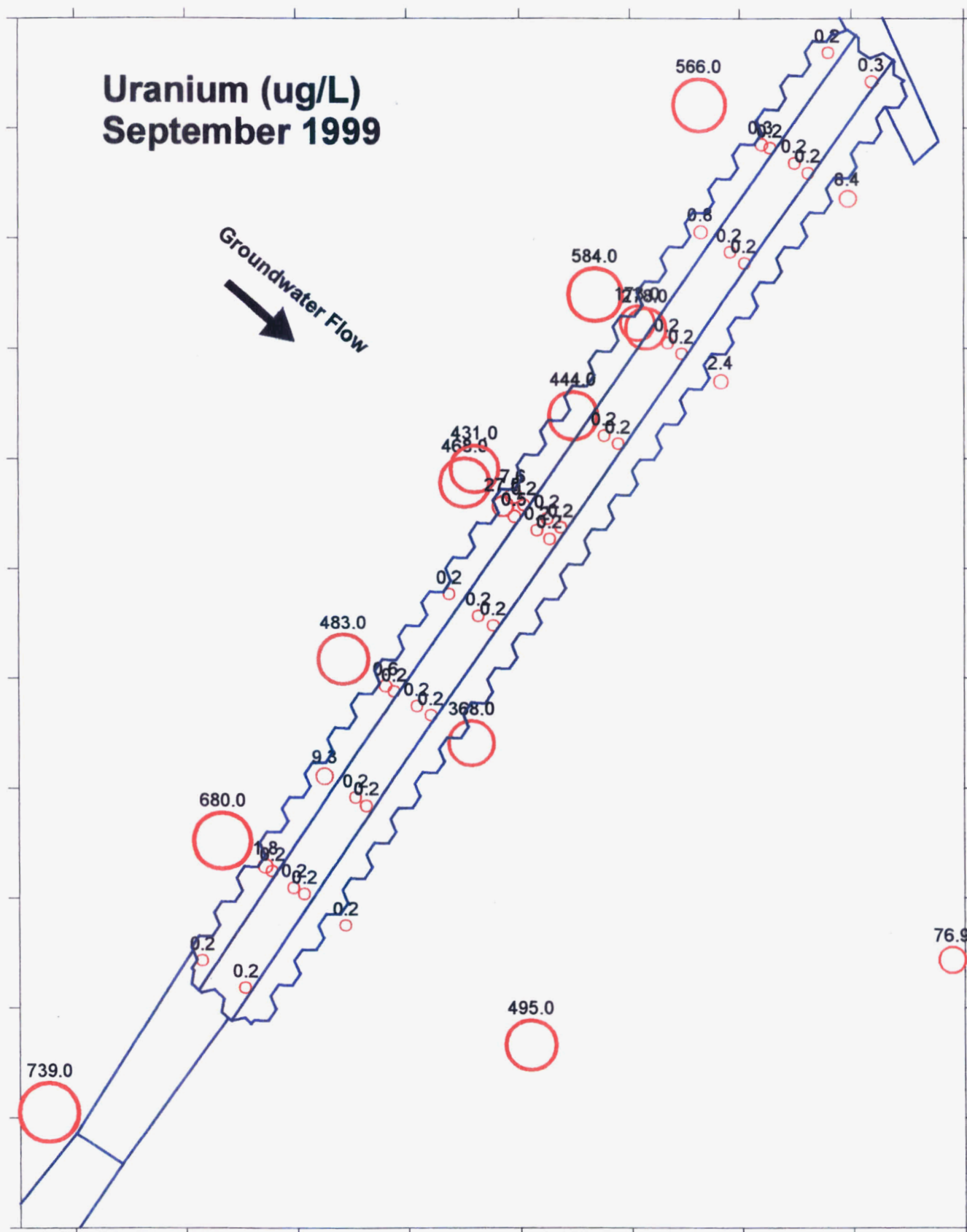


Figure 4-8. Uranium Sampling Data

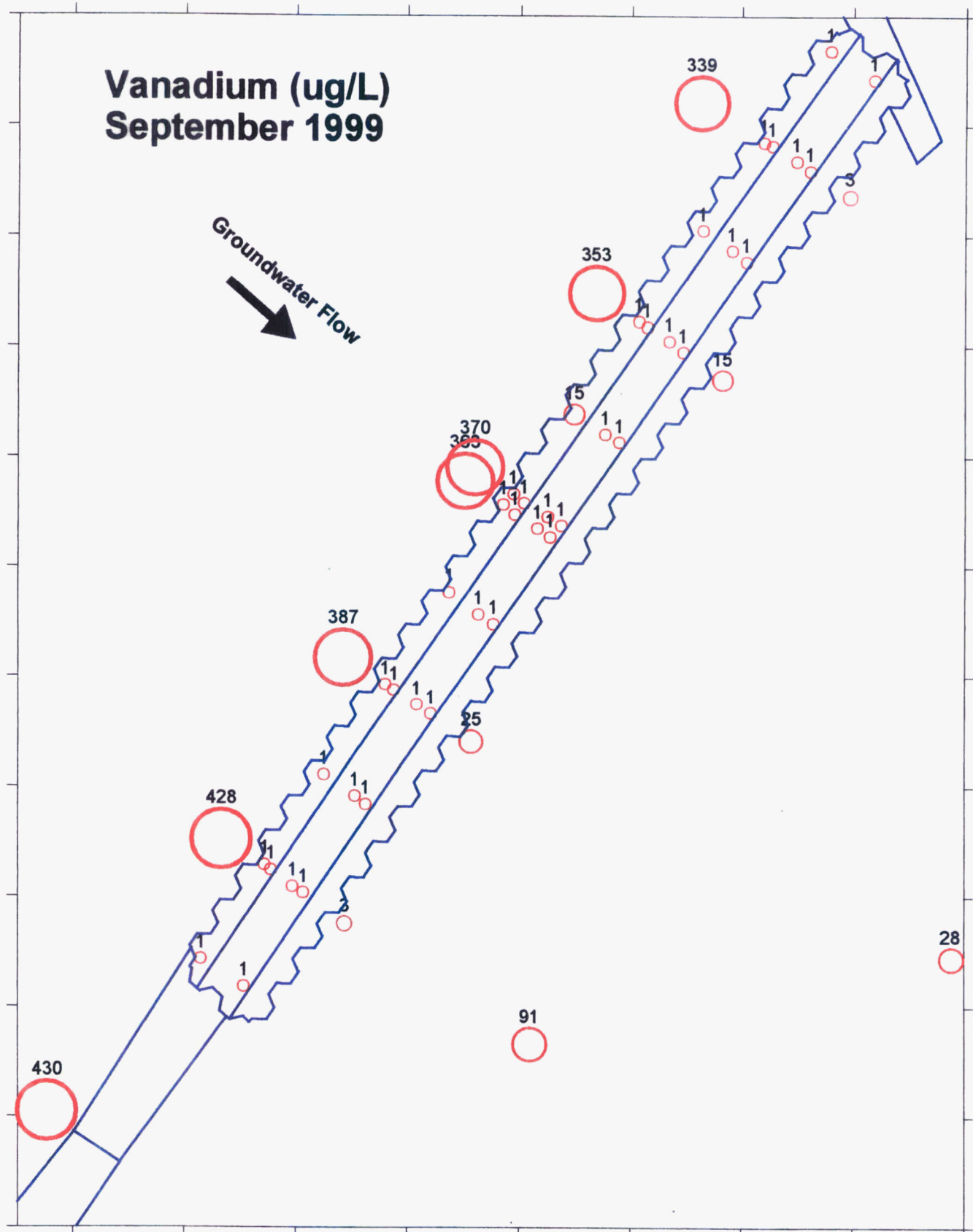


Figure 4–9. Vanadium Sampling Data

5.0 Overall Project Costs

Table 5-1 presents the overall project costs through November 19, 1999. These data have been taken from the Grand Junction Cost Control System. Laboratory costs for FY 2000 have not been included (they are estimated to be approximately \$100,000) even though they are partially costed. This will be adjusted as the actual costs are known.

Table 5.1-1 PeRT Wall Project Costs

Cost Element	FY 1998	FY 1999	FY 2000 ¹		Total
Qualification Strategy					
Review of Monticello Data	\$25,100	\$0	\$0		\$25,100
Regulatory Interface	\$1,300	\$0	\$0		\$1,300
Characterization ³	\$59,800	\$300	\$0		\$60,100
Tracer Study Design	\$5,000	\$0	\$0		\$5,000
Performance Modeling	\$2,500	\$0	\$0		\$2,500
Risk Assessment Impacts	\$500	\$0	\$0		\$500
Laboratory Treatability Study	\$36,700	\$0	\$0		\$36,700
Field Treatability Study	\$66,700	\$0	\$0		\$66,700
Design of PeRT Wall	\$61,200	\$17,300	\$0		\$78,500
Design of Monitoring Network	\$11,100	\$11,400	\$0		\$22,500
Intergration of Other PeRT Projects	\$5,000	\$800	\$0		\$5,800
Project Management ⁴	\$53,900	\$82,000	\$13,200		\$149,100
Total Qualification Strategy	\$328,800	\$111,800	\$13,200		\$453,800
Implementation Strategy					
Construction Preparation	\$57,900	\$74,500	\$0		\$132,400
Site Preparation	\$0	\$4,400	\$0		\$4,400
Emplacement	\$0	\$986,600	\$0		\$986,600
Site Restoration ²	\$0	\$0	\$0		\$0
ASTD Monitoring	\$0	\$50,300	\$21,900		\$72,200
Total Implementaion Strategy	\$57,900	\$1,115,800	\$21,900		\$1,195,600
Deployment Strategy					
Deployment/Communication Transfer	\$5,000	\$3,200	\$8,800		\$17,000
Deployment at Other Sites	\$0	\$0	\$2,400		\$2,400
Total Deployment Strategy	\$5,000	\$3,200	\$11,200		\$19,400
Grand Total	\$391,700	\$1,230,800	\$46,300		\$1,668,800

Notes:

1. FY 2000 is for fiscal October and November only.
2. Site restoration has been included with emplacement.
3. Includes laboratory costs of \$32,000 in FY 1998 and \$300 in FY 1999.
4. This includes a lease payment of \$20,000 to the landowner to construct and monitor the PeRT wall. An additional payment of \$20,000 will be made in FY 2000.

This page intentionally blank

Appendix A
PeRT Wall Bibliography

This page intentionally blank

Cromwell, 1998. "Results of Preliminary Groundwater Flow Models for Baseline and Various Permeable Reactive Treatment (PeRT) Wall Configurations at Monticello, Utah." Memorandum to Mr. Paul Mushovic (U.S. Environmental Protection Agency, Region VIII) and Mr. David Bird (State of Utah Department of Environmental Quality) from Mr. Vernon Cromwell (DOE-Grand Junction Office) dated May 27.

"Flow Modeling Summary for Monticello PeRT Project," Letter to Vernon Cromwell, From Tim Bartlett, June 16, 1998.

MACTEC Environmental Restoration Services (MACTEC-ERS), "Monticello PeRT Project Field Characterization Summary, prepared by MACTEC-ERS for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, March.

———, 1999. *Final QC Plan, Revision 1, Slurry Wall Construction Monticello Permeable Reactive Treatment (PeRT) Project, Monticello, Utah*, May.

Memo to Permeable Reactive Treatment (PeRT) Wall File, From Clay Carpenter, "Potential Reduction in risks to Human health From Use of the PeRT Wall," March 31, 1998.

Morrison, S.J., 1998. *Research and Application of Permeable Reactive Barriers*, prepared for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, April.

Somerville, R.K, Z.M, 1999. "Grant of Easement," prepared by MACTEC Environmental Restoration Services for the U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, April.

U.S. Department of Energy, 1997. *Deployment Plan for the Permeable Reactive Treatment Wall for Radionuclides and Metals*, GJO-97-35-TAR, November.

———, 1998. *Permeable Reactive Treatment (PeRT) Wall Results of Laboratory Treatability Testing for the Monticello PeRT Wall*, GJO-98-52-TAR, prepared by MACTEC for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, May.

———, 1998. *Monticello Projects, Monticello Permeable Reactive Treatment Wall, Project Safety Plan for Monticello Millsite Permeable Reactive Treatment (PeRT) Wall Groundwater Treatment System*, Revision 0, MAC-PTW 2.1.3, prepared by MACTEC-ERS for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, August.

———, 1998. *Record of Decision for an Interim Remedial Action at the Monticello Mill Tailings Site, Operable Unit III—Surface Water and Ground Water, Monticello, Utah*, GJO-98-51-TAR, prepared by MACTEC Environmental Restoration Services for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, August.

———, 1998. *Permeable Reactive Treatment (PeRT) Wall, Characterization Report*, MAC-PTW 1.3-1, prepared by MACTEC-ERS for the U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, September.

———, 1998. *Permeable Reactive Treatment (PeRT) Wall Results of Field Treatability Studies for the Monticello, Utah, PeRT Wall*, GJO-98-69-TAR, prepared by MACTEC for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, November.

U.S. Department of Energy (DOE), 1998. *Permeable Reactive Treatment (PeRT) Wall Project, Monitoring Well Network Design for the Monticello Millsite PeRT Wall Groundwater Treatment System*, prepared by MSE Technology Applications, Inc. for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, December.

———. 1999. *Permeable Reactive Treatment Wall, Summary Design Report for the PeRT Wall at Monticello, Utah*, Draft, prepared by MACTEC-ERS for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, February.

———, 1999. *Permeable Reactive Treatment (PeRT) Wall Design Specifications for the Monticello Millsite PeRT Wall Groundwater Treatment System*, MAC-PTW 1.8-2, prepared by MACTEC for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, May.

———, 1999. *Permeable Reactive Treatment (PeRT) Wall, Annual Report on Deployment Commitments*, prepared by MACTEC-ERS for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, September.

Work Readiness Review for the Monticello PeRT Wall Project Site Characterization and Field Treatability Activities, May 20, 1998.